NASA Facts

National Aeronautics and
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The Earth Science Enterprise Series

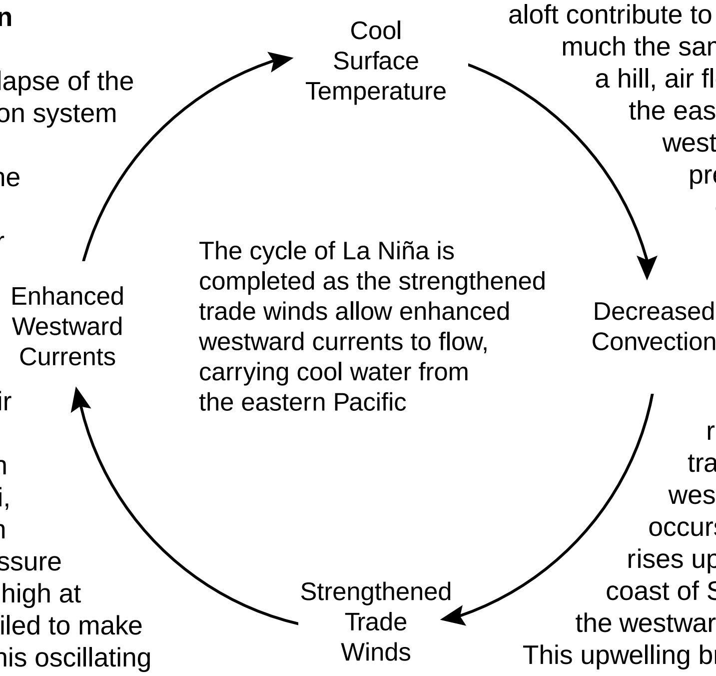
These articles discuss Earth's many dynamic processes and their interactions

La Niña

The coupled atmosphere-ocean phenomenon known as El Niño is frequently followed by a period of normal conditions in the equatorial Pacific Ocean. Sometimes, but not always, El Niño conditions give way to the other extreme of the El Niño-Southern Oscillation (ENSO) cycle. This cold counterpart to El Niño is known as La Niña, Spanish for “the girl child.”

The Southern Oscillation

While researching the collapse of the rainy phase of the monsoon system and resulting drought that occurred in India during the early years of the 20th century, Sir Gilbert Walker discovered a seesaw variation in pressure between the eastern and western Pacific Ocean. Walker found that when air pressure was high at Darwin, Australia (western Pacific) it was low at Tahiti, French Polynesia (eastern Pacific), and when air pressure was low at Darwin, it was high at Tahiti. Walker, however, failed to make the connection between this oscillating pressure pattern and El Niño. This link was made convincingly in the 1960s by the Norwegian meteorologist Jacob Bjerknes, who was also researching the anomalous drought in India.



The cycle of La Niña is completed as the strengthened trade winds allow enhanced westward currents to flow, carrying cool water from the eastern Pacific

How La Niña Forms

Researchers discovered that during non-El Niño years, surface pressures tend to be low over the warm waters of the equatorial western Pacific as overlying warm moist air rises and then diverges aloft. Over the colder waters of the eastern equatorial Pacific, surface pressures tend to be higher as converging winds aloft contribute to the sinking of cool air. In much the same way as a ball rolls down a hill, air flows from high pressure in the east to low pressure in the west along this equatorial pressure gradient. This contrast in pressure is what drives the trade winds, the prevailing large-scale surface winds that blow from east to west. As these winds blow along the surface of the equatorial waters, there is a net transport of ocean water in a westward direction. As this occurs, cold, nutrient-rich water rises up (or upwells) along the coast of South America to replace the westward-moving surface water. This upwelling brings nutrients to the surface waters off the coast allowing the fish population living in these upper waters to thrive.

During La Niña years, the trade winds are unusually strong due to an enhanced pressure gradient between the eastern and western Pacific. As a result, upwelling is enhanced along the coast of South America, contributing to colder than normal surface waters over the eastern tropical Pacific and warmer than normal surface waters in the western tropical Pacific (Figures 1 and 2).

The Effects of La Niña

Changes in global atmospheric circulation patterns accompany La Niña and are responsible for weather extremes in various parts of the world that are typically opposite to those associated with El Niño. These patterns result from colder than normal ocean temperatures inhibiting the formation of rain-producing clouds over the eastern equatorial Pacific region while at the same time enhancing rainfall over the western equatorial Pacific region (Indonesia, Malaysia and northern Australia.) These patterns affect the position and intensity (weakening) of jet streams and the behavior of storms outside of the tropics in both the Northern and Southern hemispheres. Inside the tropics, ENSO strongly affects tropical cyclone activity around the world. During La Niña, weakened jet streams contribute to an increase in the number of Atlantic tropical storms and hurricanes. During El Niño, strengthened jet streams contribute to a decrease in tropical cyclone activity in the Atlantic and Australian basins.

U.S. La Niña Impacts

The first three months of the year during a La Niña typically feature below normal precipitation in the Southwest, the central and southern sections of the Rockies and Great Plains, and Florida. Meanwhile, the odds of surplus precipitation increase across the Pacific Northwest, in the northern Intermountain West, and over scattered sections of the north-central states, Ohio Valley, and upper Southeast. La Niña features unusually cold weather in the Northwest

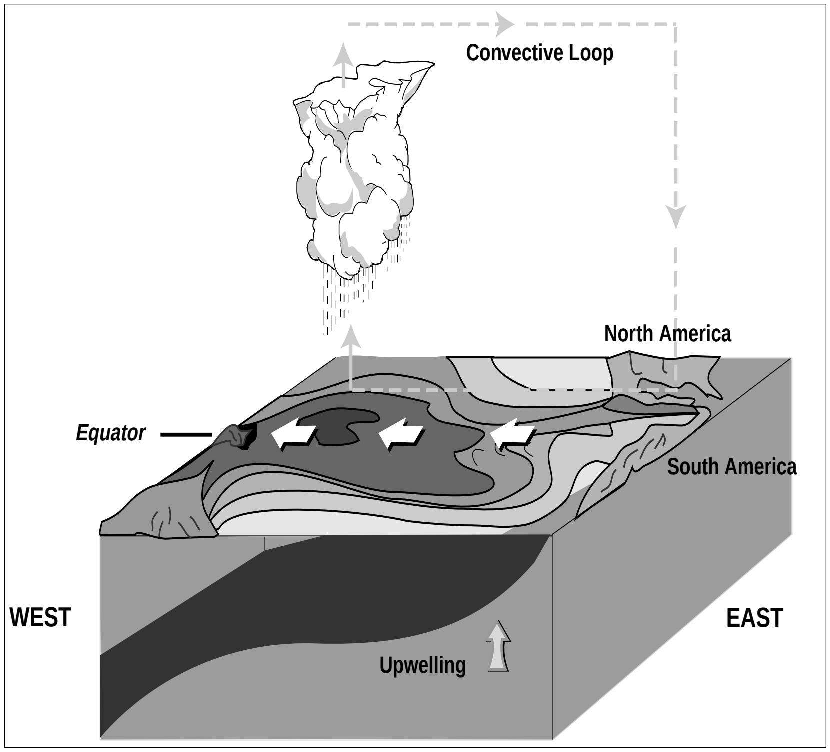


Figure 1. Normal conditions over the Pacific basin.

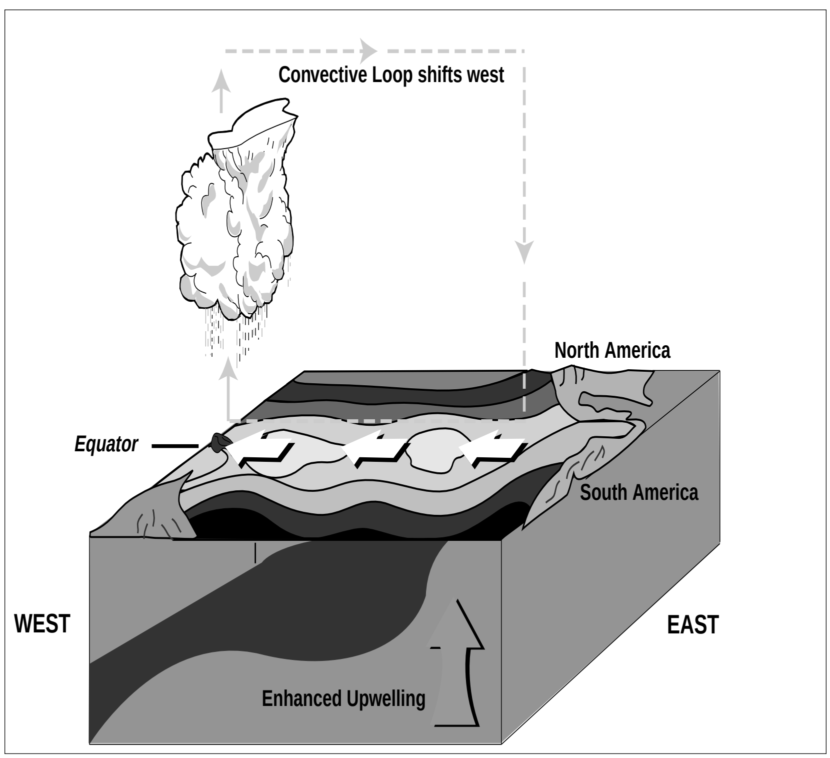


Figure 2. Disturbed conditions over the Pacific basin during a La Niña.

and (to a lesser extent) northern California, the northern Intermountain West, and the north-central states. Farther south, higher than normal temperatures are slightly favored in a broad area covering the southern Rockies and Great Plains, the Ohio Valley, the Southeast, and the mid-Atlantic states.

Global La Niña Impacts

Globally, La Niña is characterized by wetter than normal conditions west of the equatorial central Pacific over northern Australia and Indonesia during the northern hemisphere winter, and over the Philippines during the northern hemisphere summer. Wetter than normal conditions are also observed over southeastern Africa and northern Brazil, during the northern hemisphere winter season. During the northern hemisphere summer season, the Indian monsoon rainfall tends to be greater than normal, especially in northwest India. Drier than normal conditions are observed along the west coast of tropical South America, and at subtropical latitudes of North America (Gulf Coast) and South America (southern Brazil to central Argentina) during their respective winter seasons (Figure 3)[1].

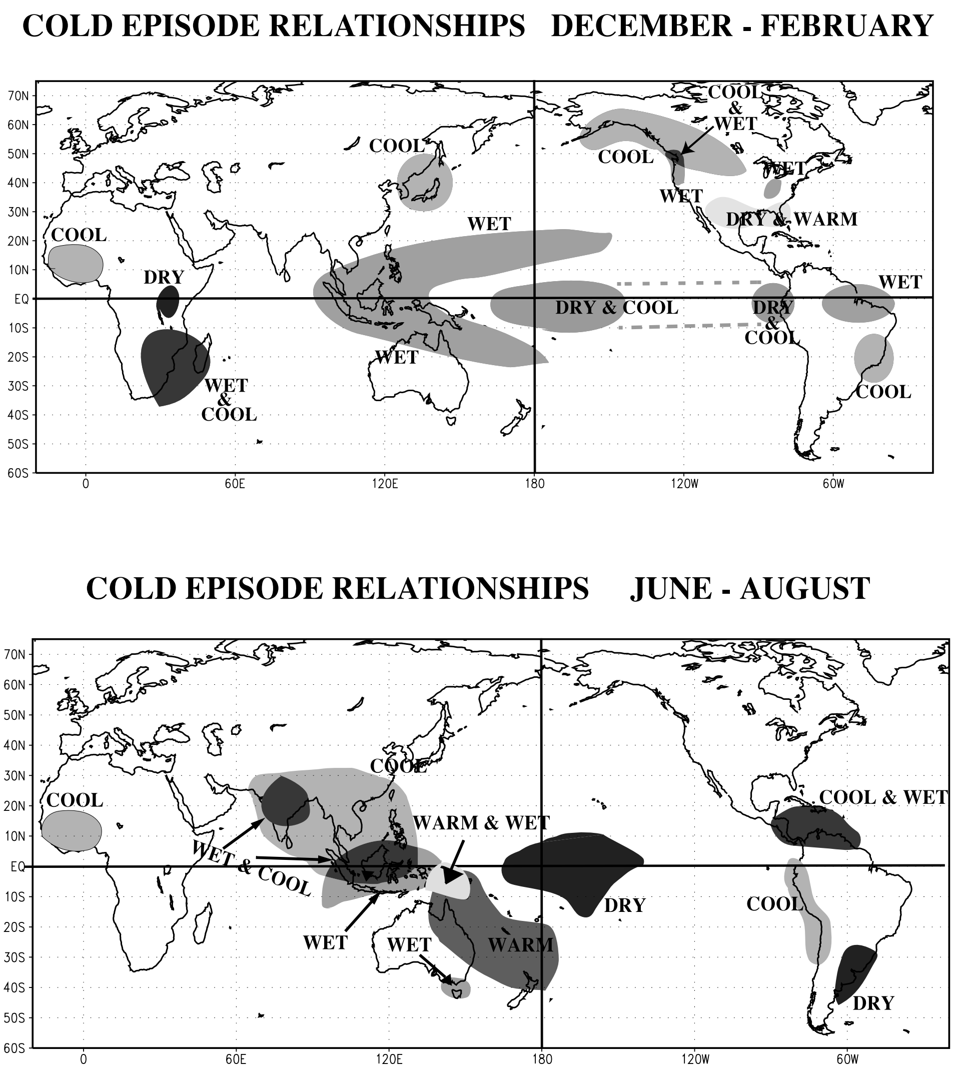


Figure 3. Anomalous precipitation and temperature patterns associated with La Niña (National Oceanic and Atmospheric Administration).

NASA and NOAA Missions to Study La Niña

Over the years, several NASA missions have studied the effects associated with La Niña and El Niño, such as changes in sea-surface temperature (SST) and cloud cover. These studies are augmented by data from operational satellites of the National Oceanic and Atmospheric Administration (NOAA).

[1]National Centers for Environmental Prediction-Climate Prediction Center (NOAA).

Initial efforts at mapping SST and cloud cover were conducted using data from NASA's Nimbus series of satellites. The four-channel Advanced Very High Resolution Radiometer (AVHRR), flown on NOAA's TIROS-N weather satellite in 1978 and on the NOAA-6 satellite in 1979, greatly increased the accurate measurements of El Niño effects. ("Four channel" means that the instrument views in four different parts of the electromagnetic visible and infrared spectrum.) Still further increases in accuracy resulted when a fifth channel was added to the AVHRR instrument flown on NOAA-7 in 1981, and on subsequent NOAA satellites. The fifth channel improved the measurement of SST by providing corrections for atmospheric water vapor that otherwise would have interfered with the temperature measurements.

The joint U.S.-French TOPEX/Poseidon mission was launched in 1992 and is providing global determinations of changes in ocean surface currents that are related to the La Niña and El Niño phenomena. Data retrieved from TOPEX/Poseidon are important because they provide measurements of the depth to which the cold or warm anomaly extends.

A NASA scatterometer called NSCAT flew on the Japanese Advanced Earth Observing System (ADEOS) spacecraft, which was launched in August 1996. NSCAT provided very high quality data on the speed and direction of ocean-surface winds worldwide. Unfortunately, after nine months in orbit, a spacecraft failure brought to an end the stream of NSCAT data. Recognizing the important contributions to Earth science made by NSCAT, NASA launched the QuikSCAT satellite in June 1999 to bridge the gap remaining before launch of the Japanese spacecraft designated ADEOS II (planned for 2000). The SeaWinds instrument onboard QuikSCAT and ADEOS II will provide detailed measurements of the winds above the oceans.

In addition to the scatterometer measurements, which use active microwave radar systems to determine surface wind speeds and directions over the ocean, surface wind speeds are also being obtained from the Special Sensor Microwave Imager (SSM/I), a passive microwave sensor onboard a Department of Defense spacecraft.

Key sources of data related to El Niño have been retrieved from the five-channel AVHRRs flown on NOAA-7, 9, and 11. These historic data sets cover the period 1981 through 1992 and beyond and will permit more-accurate SST determinations than were previously available. These data are important to the development and testing of a new generation of computer models in which the interacting processes of the land, the atmosphere, and the oceans are coupled. These coupled models will lead the way to an increased understanding of phenomenon such as La Niña and the teleconnections that link La Niña with changes in weather patterns throughout the world.

NASA's SeaWiFS (Sea-viewing Wide Field of View Sensor) was launched on the OrbView-2 satellite in August 1997. SeaWiFS is designed to detect ocean color, which is an indicator of microscopic plant life in the ocean. The growth of such plants (called phytoplankton) is affected by the changes in sea surface temperature that are related to La Niña and El Niño. SeaWiFS data enable scientists to compare and contrast El Niño's impacts on the marine biosphere with those of La Niña.

The Tropical Atmosphere Ocean (TAO) Array consists of nearly 70 moored buoys in the tropical Pacific designed by the National Oceanic and Atmospheric Administration (NOAA). These floating devices take real-time measurements of air temperature, relative humidity, surface winds, sea surfaces temperatures and subsurface temperatures down to a depth of 500 meters. Data from these moored buoys are processed by NOAA and then made available to scientists for collaborative research studies.

The joint U.S.-Japanese Tropical Rainfall Measuring Mission (TRMM), launched in November 1997, uses for the first time both active (radar) and passive microwave detectors from space to provide measurements of precipitation, clouds, and radiation processes in lower latitudes, including those portions of the Pacific Ocean where El Niño and La Niña occur. TRMM research team members have successfully retrieved sea-surface temperature data from the TRMM Microwave Imager (TMI) instrument onboard the spacecraft, giving them new insight into the complex evolution of the La Niña event. TMI is an all-weather measuring instrument that can see through clouds to measure sea-surface temperature in the tropics. Similar observations will be continued by the Advanced Microwave Scanning Radiometer (AMSR) to be flown on ADEOS-II and the AMSR-E instrument to be flown onboard EOS PM-1, both of which will be launched in the year 2000.

With the launch of the EOS satellites, we will have the means to collect and analyze the most comprehensive data set ever acquired for the development of coupled models. This data set will increase markedly our understanding of the causes and effects of such large-scale ocean-atmosphere phenomena as La Niña and El Niño.